ABSTRACT: This work presents a study of the energetic and environmental potentialities of the use of Jatropha Curcas L. in the south coastal part of the Guantánamo province, Cuba for production of biodiesel as an alternative for the sustainable energy development. A quantitative and qualitative evaluation of the Jatropha Curcas components and by-products of the biodiesel production in the area including its physical and chemical properties is performed. The possible uses and energetic contribution of the Jatropha components and by-products from biodiesel production such as the fruits, shell, seed, oil, cake, fuel wood, glycerol are evaluated. Social, environmental and economical impacts are described. The contribution of the Jatropha Curcas to the Cuban energetic matrix is compared with other Cuban agro-industries such as sugarcane, coconut and coffee.

Keywords: biodiesel, sustainable use of biomass, esterification

1 INTRODUCTION

Biodiesel extracted from vegetable oil is an alternative renewable fuel source reducing the dependence on fossil fuels. A plant deserving special attention for biodiesel production is Jatropha curcas, a plant which is been used to combat desertification.

Jatropha curcas L. (JCL) is a tall bush or small tree (up to 5 m high) and belongs to the euphorbia family. The genus Jatropha contains approximately 170 known species. Jatropha has a speedy growth curve, and produces seeds for well over for 50 years. The seeds contain more than 30% of a nonedible oil. The genus name Jatropha derives from the Greek *jatrós* (doctor), *trophé* (food), which implies medicinal uses.

The centre of Jatropha origin is Mexico and Central America. It has been introduced to Africa and Asia and is now culit-vated world-wide specially in tropical and subtropical countries. Currently it is used as a living fence to protect gardens and fields from animals. In Cuba Jatropha is present in the entire island.

The area under cultivation of Jatropha is expanding several countries such as India, Brazil, Guatemala, some Africans countries. In Cuba, CITMA, MINAZ with the support of MINAZ are developing energetic cultivation in Guantánamo and Granma.

The development of the cultivation of Jatropha as energy source is aiming also:

- To reduce poverty, especially that of women, by stimulating economic activities in rural areas by using the products of such plants for the manufacture of soap, medicines, lubricants, chemicals, fertilizers, insecticides.
- Prevention of water erosion. Improvement of soil fertility.
- Improvement of the quality of life in rural areas, encouraging the use of plant oil as a viable renewable energy option for cooking, lighting and heating.
- A reduced consumption of firewood and residues in rural areas.
- Expanded options for carbon dioxide abatement.
- A reduction of expenditure of imported fuels for rural consumption,
- The establishment of decentralized technology chains based on the use of plant oil.
- Energy production in rural areas as well as rural mechanisation promoting the use of plant oil as a fuel in stationary or mobile engines for water pumping (irrigation), grain milling, transportation and electrical generation.

2 MATERIALS AND METHODS

The goal of the work is to evaluate an agro-forestry system of Jatropha in the arid conditions such as in the south coastal part of the Guantánamo province. A quantitative and qualitative evaluation of the Jatropha Curcas components and by-products of the biodiesel production in the area including its physical and chemical properties is performed. The heat value is determined by experimental methods (calorific pump) as well by analytical methods (by using the elemental composition of the fuel, C-H-O-N-S, humidity, ash yield). The Production of Jatropha curcas and production of energy in the agro-forestry system were estimated. The appropriated technology was selected and designed

2.1 Characteristic of the fruits.

Fruits are about 2 cm in diameter. Each fruit contains 2-3 seeds. Jatropha cultivation are estimated to produce 3500 kg fruits /ha, (base: 400 trees/ha and fruit weigh: 3.3 g).

2.2 The shell.

The separation of the shell from the nut can be done manually or by a shelling machine. The shell can be used
as organic fertilizer. The shell is 30 wt% of the fruit. 1000 kg shell can be produced in 1 ha. The shell can be also used as fuel. The calorific value of the shell is 11.1 MJ/kg (15% humidity).

The shell can be also used in bio-digester to produce biogas. In Nicaragua considerable production of biogas using shell of Jatropha in an upflow anaerobic digestor has been obtained with a retention time of 3 days.

2.3 The seed.

The seed is 70 %wt of the fruit. 2500 kg seed could be produced in 1 ha. The size of the seed is about 17.5 mm in length and 11.5 mm width. The weight of 1000 seed is about 840 g, i.e. 1190 seed/kg.

The Cape Verde seed variety is smaller (682 g/1000 seed). This type is very common around the world but not in America Central. In Cuba 9 ha has been cultivated with this type in the region of Guantanamo and Granma, with good adaptation to the dry conditions. The process is in evaluation.

The Nicaragua seed variety has a weight of 878 g/1000 seeds. This type produces less fruit per tree than the African type.

In Mexico, in the region of Misantla, Veracruz, there is a non toxic variety.

The composition of the seed is about 6,6 wt% water, 18.2 %wt protein, 38 wt% oil, 33.5 wt% carbohydrate, 15.5 wt% fibre and 4.5 wt % ash.

2.4 The oil.

The seed contains about 38 %wt oil. Between 27 % and 32 % oil can be mechanically extracted from seed using a screw press. The oil is used for production of soap, of insecticide, etc. It can be used as fuel as pure oil or as biodiesel after its transesterification. As biodiesel can be used in mixtures B2, B5, B10, B20 or pure (B100).

Using the Sundhara oil expeller, extractions of around 29% has been obtained.3.3 kg of seed has been used for production of 1 kg oil (1.086 litres oil) with the following physical -chemical properties (table 1)

<table>
<thead>
<tr>
<th>Properties</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calorific value, MJ/kg</td>
<td>39.08</td>
</tr>
<tr>
<td>Relative density a $15^\circ$ C g/cm$^3$</td>
<td>0.9207</td>
</tr>
<tr>
<td>Kinematic viscosity a $20^\circ$ C cst</td>
<td>44.31</td>
</tr>
<tr>
<td>Relation C/H, %wt</td>
<td>13.11</td>
</tr>
<tr>
<td>Sulphur content, % wt</td>
<td>0.04</td>
</tr>
<tr>
<td>Water content, % wt</td>
<td>0.21</td>
</tr>
</tbody>
</table>

2.5 The cake.

After the extraction of oil from seeds the remnant matter or cake are left as by-product. The cake containing carbohydrates, fibres and rest of oil is useful as organic fertilizer because the high content of nitrogen. Jatropha oil cakes are used for a wide variety of applications and can be further processed to make biogas. The cake contains toxic components, but after these components are taking away, the cake could be used as animal food with a protein contain higher than 50%.

About 1000 kg of cake /ha can be obtained. The cake could also be used as fuel, because its calorific value is 11.1 MJ/kg (3% humidity). The Mexican variety is non toxic and for this reason the produced cake has a higher economic value.

2.6 The fuel wood

During 6 year, 20 000 kg biomass can be produce in 1 ha of Jatropha plantation (considering 20 kg/tree and 40 tree/ha)

The wood produced during the thinning out and maintenance of the plantation has a calorific value of 15.5 MJ/kg (15% humidity). The wood can be used as living fence, because it is not browsed by animals, as fuel wood or for production of charcoal.

For an environmental point of view each tree can fix 6 kg CO$_2$ and 9 kg O$_2$. The tree contribute to the reforestation in arid and semi-arid regions rehabilitating degraded areas, protecting the land from wind erosion, protecting the biodiversity in coastal areas.

If the nutrient supply to the plant is adequate, especially in nitrogen, the evolution of the plant depends on the water disponibility. The net production of biomass including the leaves, wood, fruit, etc can reach a level of 1.2 t/ha/year of dry mater with rains in the level of 200 mm/year. In areas where the rains are in the level of 1500 mm/year the net production of biomass can be 11.8 t/ha/year.

2.7 The glycerol.

During the manufacture of biodiesel, for every 1 litre of oil which is processed by transesterification, 79 ml of glycerol is produced, i.e. 64.3 litres glycerol is produced in 1 ha. Jatropha plantation. The produced by-product in the transesterification reaction is a mixture of glycerol, soap, unreacted alcohol and catalyst (Potassium or Sodium hydroxide). This mixture can be destillated in order to obtain pure glycerol to be used as raw material or as fuel in the production of biogas.

The residues from the transesterification reaction can be converted biologically or thermally into energy. Since 2001 the production of biogas using glycerol is being studied. Studies regarding the elimination of undesired compounds produced in the transesterification and mixed with the glycerol.

The thermal conversion of glycerol into energy is an alternative to developed in the future taking into account that the calorific value of the glycerol is 17.28 MJ/kg. The glycercine by-product burns well, but unless it's properly combusted at high temperatures it will release toxic acrolein fumes (unsaturated aldehyde), which mainly form at between 200 and 300 °C. Skin exposure to acrolein causes serious damage. Acrolein concentrations of 2 ppm are immediately dangerous to life. Permissible exposure limit for acrolein is 0.1 ppm. A complete and clean combustion of the glycerol requires a burning temperature in excess of 1,000 °C and probably a mean residence time in the Hot Box of about 5 seconds.

The glycercine has several uses. The most important applications are related to the pharmaceutical industry, the food industry as well as the cosmetic industry.
3 RESULTS and DISCUSSION

In the arid and semi-arid regions of Cuba, two harvests can be performed yearly, one in December-February and another with a lower yield in July-September.

The energetic cultivation of Jatropha increases the production yield after the third year reaching a stable yield in the sixth year. At this time the productivity levels in an arid and semi-arid region will be as following (figure 1):

<table>
<thead>
<tr>
<th>Product</th>
<th>Energy Content (MJ/kg)</th>
<th>Quantity (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,300 kg fruit</td>
<td>21.2</td>
<td>1,230</td>
</tr>
<tr>
<td>2,500 kg seed</td>
<td>25.5</td>
<td>1,070</td>
</tr>
<tr>
<td>1,000 kg shell</td>
<td>11.1</td>
<td>440</td>
</tr>
<tr>
<td>750 kg oil</td>
<td>39.08</td>
<td>342</td>
</tr>
<tr>
<td>1,750 kg cake</td>
<td>7.23</td>
<td>723</td>
</tr>
<tr>
<td>750 kg biodiesel</td>
<td>17.26</td>
<td>719</td>
</tr>
<tr>
<td>771 kg glycerol</td>
<td>17.26</td>
<td>719</td>
</tr>
</tbody>
</table>

Figure 1. Energetic characteristic of Jatropha components

In figure 1 the energetic characteristic of Jatropha components is shown. The biomass with higher economic value are the oil and the glycerol, because of their several uses, energetic potentialities and the actual state of the technological development allowing its energetic utilization as well as their industrial uses such as soap, cosmetics, insecticides, lubricants, etc.

The shells of the fruits and seeds as well as the residual cake are used today as fertilizers. Research is aiming to convert this biomass into energy by biological conversion to produce biogas and by thermal conversion to produce heat.

An agro-forestry system could theoretical produce energy levels over 1.835 toe (ton equivalent petroleum: 45 · 10³ MJ) not including the contribution of the fuel wood. The biomass production can be increased with an optimal irrigation and fertilization.

3.1 Impacts

The main impact of an agro-forestry system based on Jatropha Curcas is the impact on the environment such as the increase of the forest area, increase of the biodiversity, soil recuperation by reduction of wind and water erosion, improvement of soil fertility, decrease of contaminant gas emissions.

4 CONCLUSIONS

The biomass production in an agro-forestry system based on Jatropha Curcas and its energetic conversion can increase the influence of biomass on the Cuban energetic matrix, reaching production of biomass in levels of 1.83 toe/ha not including the contribution of the fuel wood. The biomass production can be increased with an optimal irrigation and fertilization. As comparison it is mentioned the contribution of other Cuban agro-industries to the Cuban energetic matrix:

- Sugar cane with 3.43 toe/ha
- Coconut with 0.97 toe/ha
- Coffee with 0.118 toe/ha

The relationship between input and output is 1: 3.5 to 1:5 for the Jatropha according international experiences, higher than the obtained in other Cuban agro-industries excepting the Coconut (1:1.8 for sugarcane; 1:0.71 for coffee and 1:22 for coconut).

An advantage of the agro-forestry system based on Jatropha Curcas is the impact on the environment such as the increase of the forest area, increase of the biodiversity, soil recuperation by reduction of wind and water erosion, improvement of soil fertility, decrease of contaminant gas emission.

5 REFERENCES